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Operating Instructions
Model 77B
Automatic Capacitance Limit Bridge

BOONTON ELECTRONICS CORPORATION

MP MASTER
MA25116

S/N 339

Operating Instructions
Model 77B
Automatic Capacitance Limit Bridge

BOONTON ELECTRONICS CORPORATION

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ERRATA No. 1

This errata material changes and amends "Operating Instructions, Model 77B Automatic Capacitance Limit Bridge" as indicated below:

Page 4-9, paragraph 4.9. Delete paragraphs 4.9 and 4.9.1 and substitute the following corrected paragraph 4.9 and Figure 4-1:

ERRATA No. 1

This errata material changes and amends "Operating Instructions, Model 172B Automatic Capacitance Limit Bridge" as indicated below:

Page 4-5, paragraph 4.9. Delete paragraph 4.9 and 4.9.1 and substitute the following corrected paragraph 4.9 and Figure 4-1:

4.9 Interpreting Manual Readings

After both capacitance and conductance are satisfactorily balanced, determine the capacitance of the test specimen by multiplying the reading on the CAPACITANCE pF dial by the decimal factor indicated by the MULTIPLY C switch setting.

The conductance of the test specimen is found by dividing the CONDUCTANCE dial G scale indication by the factor indicated on the DIVIDE G MULTIPLY R switch. Figure 4-1 shows the correction factors for measurements made with the MULTIPLY C switch in the X1 position and the test specimen connected directly to the TEST binding posts or coaxial connectors on the front panel.

At all settings of the MULTIPLY C switch except the X1 position, the equivalent shunt resistance is determined by multiplying the CONDUCTANCE dial R scale reading by the factor indicated on the DIVIDE G MULTIPLY R switch. When the MULTIPLY C switch is in the X1 position, the equivalent shunt resistance is found by determining the conductance, applying the correction shown in Figure 4-1, and taking the reciprocal. For example, assume that the test specimen is a 200 pF mica capacitor, the MULTIPLY C switch in the X1 position, the DIVIDE G MULTIPLY R switch at X1000, and the CONDUCTANCE dial R scale reads 40. This reading is equivalent to 0.04 μmho. Figure 4-1 indicates that the conductance correction for a 200 pF capacitor is 0.02 μmho. Subtracting this from the measured value gives 0.02 μmho as the corrected conductance. The reciprocal of 0.02 μmho is 50 megohms. This is readily verified by using the CONDUCTANCE dial to convert from μmho to ohms. 0.02 μmho on the G scale corresponds to 50K ohms on the R scale, and the X1000 multiplier gives 50 megohms as the equivalent shunt resistance.

$$\left(R = \frac{1 \times 10^6}{G} \quad \text{where G is in micromhos}\right)$$

The Q and dissipation factor D of the measured sample may be computed from the following formulas:

$$Q = \frac{2\pi \quad fC}{G} = \frac{\omega C}{G} \qquad D = \frac{1}{Q}$$

Therefore at 1 MHz, $Q = 6.28 \frac{C}{G}$

Where:

C = test specimen capacitance in pF,
G = test specimen conductance in micromhos,
f = frequency in megahertz.

4.9 Interpreting Manual Readings

After both capacitance and conductance are satisfactorily balanced, determine the capacitance of the test specimen by multiplying the reading on the CAPACITANCE pF dial by the decimal factor indicated by the MULTIPLY C switch setting.

The conductance of the test specimen is found by dividing the CONDUCTANCE dial G scale indication by the factor indicated on the DIVIDE G MULTIPLY R switch. Figure 4-1 shows the correction factors for measurements made with the MULTIPLY G switch in the X1 position and the test specimen connected directly to the TEST binding posts or coaxial connectors on the front panel.

At all settings of the MULTIPLY G switch except the X1 position, the equivalent shunt resistance is determined by multiplying the CONDUCTANCE dial R scale reading by the factor indicated on the DIVIDE G MULTIPLY R switch. When the MULTIPLY G switch is in the X1 position, the equivalent shunt resistance is found by determining the conductance, applying the correction shown in Figure 4-1, and taking the reciprocal. For example, assume that the test specimen is a 200 pF mica capacitor, the MULTIPLY G switch in the X1 position, the DIVIDE G MULTIPLY R switch at X1000, and the CONDUCTANCE dial R scale reads 40. This reading is equivalent to 0.04 umho. Figure 4-1 indicates that the conductance correction for a 200 pF capacitor is 0.02 umho. Subtracting this from the measured value gives 0.02 umho as the corrected conductance. The reciprocal of 0.02 umho is 50 megohms. This is readily verified by using the CONDUCTANCE dial to convert from umho to ohms. 0.02 umho on the G scale corresponds to 50% ohms on the R scale, and the X1000 multiplier gives 50 megohms as the equivalent shunt resistance.

$$(R = \frac{1 \times 10^6}{G} \text{ where G is in micromhos})$$

The Q and dissipation factor D of the measured sample may be computed from the following formulas:

$$Q = \frac{2\pi fC}{G} = \frac{\omega C}{G} \qquad D = \frac{1}{Q}$$

Therefore at 1 MHz, $Q = 6.29 \frac{C}{G}$

Where:

C = test specimen capacitance in pF,
G = test specimen conductance in micromhos,
f = frequency in megahertz.

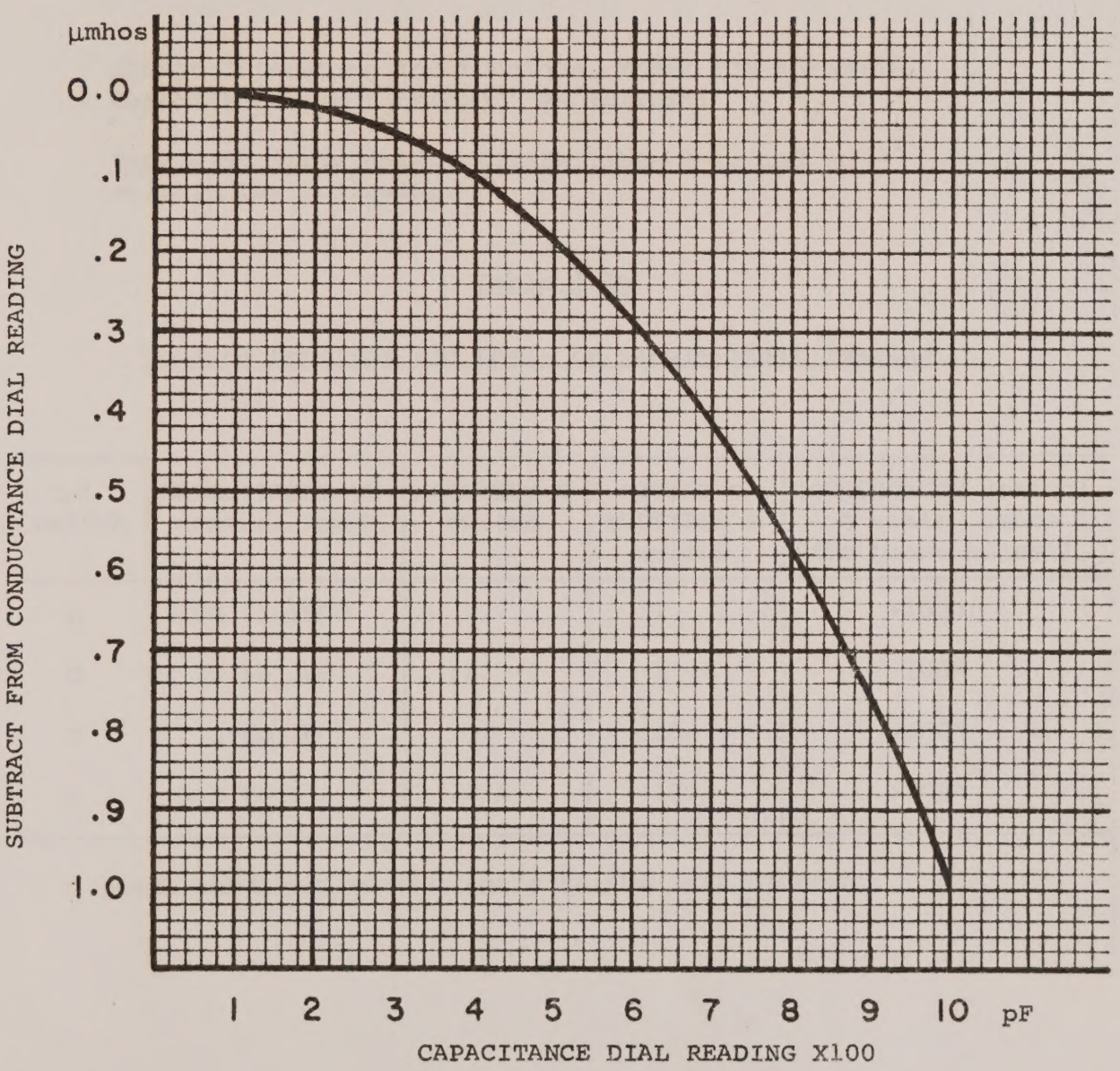

Figure 4-1. Conductance Correction for X1 Setting

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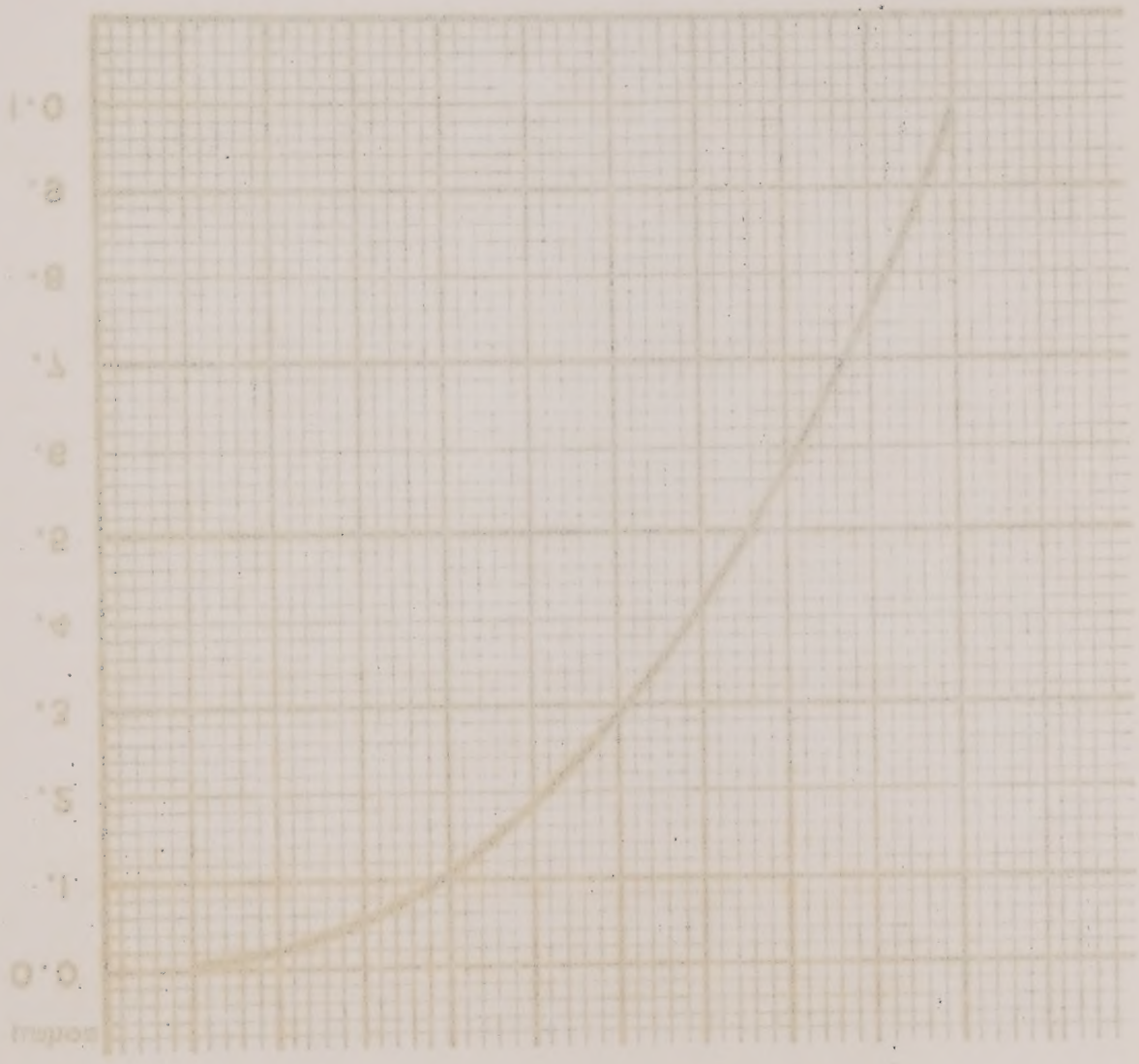

ERRATA No. 2

Change "Operating Instructions, Model 77B Automatic Capacitance Limit Bridge" as follows:

Page 4-6, Table 4-1a. Delete Table 4-1a and substitute the following:

Table 4-1a

Control Settings for Dual- or Single-Limit Testing

C/L switch	CAPACITANCE pF control range	MULTIPLY C switch	DIVIDE G MULTIPLY R switch	CONDUCTANCE control, G scale μmhos (for phase adjust)
L	100 to 1000	1	1	+1000
C	10 to 100	.1	1	-100*
C	1 to 10	.01	10	-100*
C	0.1 to 1	.001	100	-100*

* Tenth subdivision on G scale to the left of zero.

ADDENDUM

In instruments having serial numbers 243 or below, the control designated in this Instruction Book as the TOL IN/TOL OUT selector is shown on the front panel as the AUTO/MANUAL switch. The AUTO position is equivalent to the TOL IN position, and MANUAL, to the TOL OUT. It is important to note that only the nomenclature has been changed. The function of this control remains as described in this Instruction Book. For the function of this control, see paragraphs 4.2.1, 4.3.5 and 4.6.

77B INSTRUCTION BOOK

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SECTION I

General Information

1-1 Specifications

CAPACITANCE MEASUREMENT:

Range: Limit Mode, 0.001 pF to 1000 pF
Manual Mode, 0.0001 pF to 1000 pF

Multiplier	Capacitance Range	Resolution	Accuracy, Manual	Accuracy, C Nominal (Automatic)
1.0	100 to 1000 pF	0.2 pF	$\pm[0.25\% + \frac{1000}{R_p}$ pF + 0.5 pF]	$\pm[(0.25 + \frac{3}{Q})\%$ + 0.5 pF]
0.1	10 to 100 pF	0.02 pF	$\pm[0.25\% + \frac{1000}{R_p}$ pF + 0.02 pF]	$\pm[(0.25 + \frac{3}{Q})\%$ + 0.05 pF]
0.01	1 to 10 pF	0.002 pF	$\pm[0.25\% + \frac{1000}{R_p}$ pF + 0.005 pF]	$\pm[(0.25 + \frac{3}{Q})\%$ + 0.005 pF]
0.001	0.05 to 1 pF	0.0002 pF	$\pm[0.25\% + \frac{1000}{R_p}$ pF + 0.001 pF]	$\pm[(0.25 + \frac{3}{Q})\%$ + 0.001 pF]
0.001	0 to 0.05 pF	0.0002 pF	$\pm[2\% + \frac{1000}{R_p}$ pF + 0.0002 pF]	$\pm[(2 + \frac{2}{Q})\%$ + 0.0001 pF]
0.0001	0 to 0.1 pF	0.0001 pF	$\pm[2\% + \frac{1000}{R_p}$ pF + 0.0005 pF]	-------

*where R_p is the equivalent parallel resistance of the test in ohms.

INDUCTANCE MEASUREMENT:

Range: Both Limit and Manual Mode, 25 μH to ∞

C Multiplier	Inductance Range	Accuracy, Manual	Accuracy of L Nominal (Automatic)
1	25 μH to 250 μH	$\pm(0.25 + L + \frac{4000\ L}{R_p})\%$	$\pm(0.25 + \frac{3}{Q} + \frac{L\mu H}{500})\%$
0.1	250 μH to 2.5 mH	$\pm(0.25 + \frac{L}{10} + \frac{4000\ L}{R_p})\%$	$\pm(0.25 + \frac{3}{Q} + \frac{L\mu H}{500})\%$
0.01	2.5 mH to 25 mH	$\pm(0.25 + \frac{L}{50} + \frac{4000\ L}{R_p})\%$	$\pm(0.25 + \frac{3}{Q} + \frac{LmH}{50})\%$
0.001	25 mH to 250 mH	$\pm(0.25 + \frac{L}{250} + \frac{4000\ L}{R_p})\%$	-------
0.0001	250 mH to ∞	$\pm(2.00 + \frac{L}{1000} + \frac{4000\ L}{R_p})\%$	-------

**where L = millihenries

R_p = ohms of parallel resistance

CONDUCTANCE MEASUREMENT:

Range: Manual only; Range, 0 to 1000 μmhos

Divider	Conductance Range	Accuracy	Resolution
1	100 to 1000 μmhos	$\pm$(10% + $\frac{Q}{500}$ % + 10 μmho)	10 μmhos
10	10 to 100 μmhos	$\pm$(5% + $\frac{Q}{500}$ % + 1 μmho)	1 μmho
100	1 to 10 μmhos	$\pm$(5% + $\frac{Q}{500}$ % + 0.1 μmho)	0.1 μmho
1000	0 to 1 μmho	$\pm$(5% + $\frac{Q}{500}$ % + 0.01 μmho)	0.01 μmho

RESISTANCE MEASUREMENT:

Range: Manual mode only; 1000 Ω to 100 M Ω

Multiplier	Resistance Range	Accuracy	Resolution
1	1 K to 10 K	$\pm$(10% + $\frac{Q}{500}$ % + $\frac{R}{10^3}$ %)	$\frac{R}{10^3}$
10	10 K to 100 K	$\pm$(5% + $\frac{Q}{500}$ % + $\frac{R}{10^4}$ %)	$\frac{R}{10^4}$
100	100 K to 1 MΩ	$\pm$(5% + $\frac{Q}{500}$ % + $\frac{R}{10^5}$ %)	$\frac{R}{10^5}$
1000	1 MΩ to ∞	$\pm$(5% + $\frac{Q}{500}$ % + $\frac{R}{10^6}$ %)	$\frac{R}{10^6}$

***where R is the measured resistance in ohms

TEST SIGNAL:	
Frequency:	1 MHz (±200 Hz) crystal controlled
Level:	Continuously adjustable from 250 mV to 1 mV; down to 15 mV for automatic mode
DC BIAS:	
Internal:	Continuously adjustable from -6 V to +150 V
External:	Up to ±400 V @ 100 mA
TOLERANCE:	
Range:	±0.0005 pF to ±200 pF, continuously adjustable
Resolution of Limits:	1% of limit or 0.0001 pF, whichever is greater
TEST TIME:	Approximately 0.05 sec.
TEST DECISION OUTPUTS:	
Visual:	Green, red, and amber panel lamps indicating "Go", "High", and "Low", respectively
Electrical:	Sample of indicator lamp filament voltages (6.3 V @ line frequency) at rear terminals
Continuity:	Relay contact closures in conformance with test decision at rear terminals
PRIMARY POWER:	105-130 V, 60 c/s 105-130 V, 50 c/s 210-260 V, 60 c/s 210-260 V, 50 c/s As indicated on identification plate
PHYSICAL CHARACTERISTICS:	
Overall (in cabinet):	11 1/4" h x 19 1/2" w x 12 3/4" d
Without Cabinet (for rack mounting):	10 1/2" h x 19" w x 10 1/8" d
Weight (with cabinet):	35 lbs.
Weight (without cabinet):	25 lbs.

AVAILABLE ACCESSORIES

The following accessories are available for use with the Model 77B. For full details, contact your Boonton Electronics Sales Engineering Representative or write directly to the factory. (See address on Title Page of this Instruction Book.)

MODEL CS -- CAPACITANCE STANDARDS - Available in any value from 0.01 pF to 1000 pF; Basic accuracy, 0.1%; designed for operation from 1 KHz to 1 MHz calibrated against references traceable to National Bureau of Standards.

Price $75.00

MODEL 77-1A REMOTE TEST FIXTURE - Convenient test fixture connects to the TEST terminals of the bridge by coaxial cables; green, amber, and red lamps on jig duplicate front panel decision outputs; supplied complete with connecting cable for decision outputs and both magnetic and spring-loaded holders for components.

Price $100.00

MODEL 77-2A RANGE EXTENDER - Precision ratio network attaches to test terminals of bridge to increase capacitance range to 0.1 μF, conductance range to 1 mho, resistance range to 1 ohm, and inductance range to 0.25 μH. Bridge accuracy is effectively unchanged and all biasing facilities are unaffected. The Model 77-2A is for use with the Model 77B in the MANUAL mode only.

Price $150.00

MODEL 77-4A RANGE DIVIDER - Divides capacitance readings by fixed factor of 10, permitting measurements down to 0.00001 pF. For MANUAL operation only.

SECTION II

GENERAL INFORMATION

2.1 General Description

The Model 77B Automatic Capacitance Limit Bridge performs high speed go/no-go dual or single limit tests of capacitance and inductance, or conventional manual measurements.

In the automatic mode any nominal value from 0.001 pF to 1000 pF and any tolerance from ±0.0005 pF to ±200 pF may be programmed for rapid go/no-go capacitance tests. Automatic inductance limit tests may be made with nominal values programmable from 25 microhenries to infinity. Inductance limits are continuously adjustable from 0 to at least ±20% of nominal. Test decision outputs are provided in visual form by indicator lamps as well as in electrical form for actuation of external equipment.

In the manual mode the instrument operates as a conventional laboratory bridge, providing direct reading measurements of capacitance, parallel resistance, and conductance. Inductance may also be determined by simple computation.

The crystal controlled 1 MHz test signal is internally supplied and is continuously adjustable from 250 millivolts to 15 millivolts for limit testing and to 1 millivolt for manual measurements.

Test specimens may be biased either by the internal dc supply whose output is continuously adjustable from -6 to +150 volts or by an external supply up to ±400 volts.

The three terminal arrangement permits remote measurements since the bridge is essentially insensitive to capacitance from either side of the test to ground. The test specimen may be connected to the bridge by coaxial cables without incurring errors due to cable capacitance.

The standard arm of the bridge is accessible at front panel BNC connectors so that external standards or balancing capacitors may be attached, permitting use as a comparison bridge or for differential measurements.

The Model 77B (including bridge and limit circuitry, test oscillator, null detector, bias supply, and decision outputs) is packaged as a single bench type unit. When removed from its case, the instrument may be mounted in a standard 19-inch rack.

SECTION III

THEORY OF OPERATION

3.1 Bridge Circuit

3.1.1 The bridge network is a modified Young Circuit. The output from the test oscillator is applied to the bridge input transformer through a low impedance link coupling. The secondary of the input transformer is an integral part of the bridge network, providing effectively two generators with a common ground which produce signals that are equal in amplitude and opposite in phase. The low impedance of the secondary minimizes the effects of cable capacitance. With the extremely tight coupling between the two secondary windings, loading effects on one side affect the other side equally. Thus, capacitance from the LO post to ground has negligible influence on the balance of the bridge.

3.1.2 Any capacitance from the HI post to ground is shunted across the detector where its only practical effect is a reduction of detector sensitivity.

3.1.3 As a result of this arrangement only the capacitance between the HI and LO posts has significant effect on the balance condition of the bridge, permitting measurements which are essentially unaffected by impedances from either side of the test to ground.

3.1.4 The main capacitance control is a precisely calibrated differential air capacitor. The incremental decrease in capacitance in one arm, as the rotor leaves that stator, is exactly the same as the incremental increase in the other arm as the rotor enters its stator.

3.1.5 Capacitance range multiplication is accomplished by selectively inserting one of the multiplier air capacitors in series between the rotor of the main balance capacitor and the high post.

3.1.6 The conductance network is in parallel with (but independent of) the capacitance network. The main conductance control is an infinite resolution potentiometer. Conductance ranges are selected by switching one of the G multiplier resistors in series between the center arm of the potentiometer and the high post of the bridge.

3.2 Test Oscillator

The test oscillator is crystal controlled and generates a 1 MHz signal. It is a modified Colpits circuit, and is characterized by excellent amplitude stability. The signal level is continuously adjustable from at least 250 millivolts to 1 millivolt.

3.3 Null Detector Systems

The instrument has two null detection systems: (a) a phase-sensitive system employed in dual and single limit testing, or in capacitance (inductance) measurements where the conductance of the specimen is not balanced; and (b) an amplitude sensitive detector for conventional balance measurements.

3.3.1 Phase Sensitive Detector

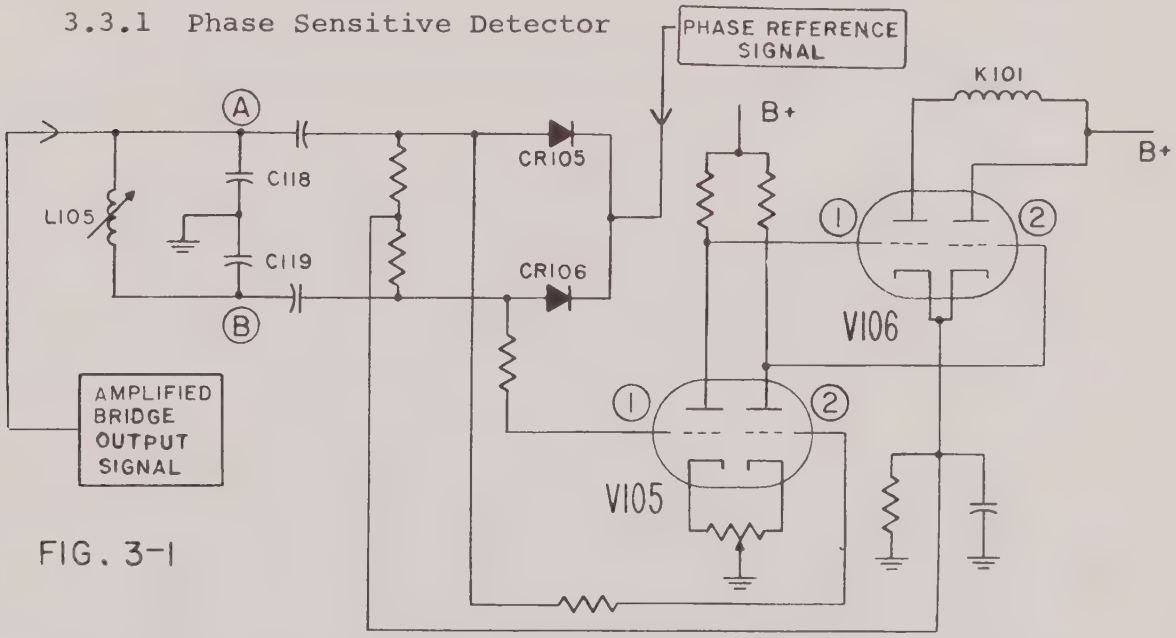


FIG. 3-1

A simplified diagram of the phase sensitive detector is shown in Figure 3-1. It comprises a balanced network having three rf inputs. One of these, the "phase reference" voltage, is applied at the junction of diodes CR105 and CR106 and is in phase with the voltage at the bridge input transformer. The other two inputs are derived by amplifying the unbalance signal from the bridge and applying it to the parallel resonant network, L105, C118, and C119 to produce voltages at points A and B which are equal in amplitude and opposite in phase.

Depending on whether the unbalancing capacitance is in the TEST or STANDARD arm, either the signal at point A or that at point B will be in phase with the phase reference.

Taking as an example the case of an unbalancing capacitance arm, the signal at point B will be in phase with the reference and will add to it, while the out-of-phase signal at point A will subtract from the reference. The resultant voltages are rectified by CR106 and CR105, respectively, and are applied to the grids of the first stage of the two-stage differential dc amplifier consisting of V105 and V106.

With the voltage at Grid 1 more negative than at Grid 2, that half of the tube will conduct less than the other. Outputs from V105 are applied to the grids of V106. With the first half of V105 conducting less than the second half, the first half of V106 is driven toward saturation, while the second half is driven near cut-off. The relay, K101 in the output circuit of V106, is energized by the plate current of the first half of V106, producing a HI decision.

If the unbalancing capacitance were in the STANDARD arm, the reverse condition would obtain, and a LO decision issued.

Any bridge unbalance signal resulting from conductance is 90 degrees out of phase with the reference voltage at one end of the resonant circuit (L105, C118, and C119) and 270 degress out of phase at the other. These inputs add vectorally to the reference, both producing the same positive change, but not contributing to a differential. Thus the loss of the test specimen does not influence the test decision.

3.3.2 Amplitude Sensitive Detector

The amplitude sensitive detector provides for conventional manual measurements in which both capacitance (inductance) and conductance (resistance) are balanced. The rectified output of the detector amplifier is monitored by the 50 microampere null indicating meter. AGC and a shaping diode provide sufficient compression that the indicator is "on scale" even with a large unbalance signal.

3.4 Tolerance Amplifier

3.4.1 Tolerance limits are established by adjusting a continuous control plus a four-position multiplier which control the output level of the tolerance amplifier.

The electronic switch operating at line frequency samples the signal voltage alternately at the standard arm and the test arm of the bridge, producing a voltage whose phase shifts

180 degrees for each half switching cycle. This voltage is applied to the tolerance amplifier, the output level of which is adjusted by the tolerance controls to equal the unbalance voltage (as seen by the detector) that would be created in the bridge by a capacitance of the value of the programmed limit.

3.4.2 Since the phase of the tolerance voltage alternates 180 degrees, the result is the same as though the programmed capacitance limit value were switched first into the standard arm and then into the test arm of the bridge.

3.5 Theory of Limit-Test Operation

3.5.1 The process of limit testing may be explained by considering the following example: Assume that 100 pF capacitors are to be tested to ±5%. The nominal value is established by setting the MULTIPLIER C selector to X1 and the main capacitance control to exactly 100 pF, which unbalances the bridge in the standard arm by that amount. The tolerance adjustment is set to ±5 pF.

Let us also assume that a specimen placed in the test fixture has an actual value of 93 pF. The tolerance amplifier applies a signal to the detector, equivalent to the addition of 5 pF to the Standard Arm for a total of 105 pF. With only 93 pF in the Test Arm, the bridge does not reach balance, the phase of the bridge output does not reverse, and the phase-sensitive detector issues a LO decision to the indicating circuitry. During the second half of the test cycle, output from the tolerance amplifier is equivalent to the addition of 5 pF to the Test Arm for a total of 98 pF, which still does not balance the bridge, and again a LO decision is issued.

3.5.2 If the actual value of the test sample were greater than 105 pF, the process would be the same, except that the bridge would pass through and beyond balance (and the phase of the bridge output would reverse) for both halves of the test cycle and the "High" indicator would remain lighted during the full cycle.

3.5.3 For a test specimen having a capacitance within the limits of 95 and 105 pF, with the 5 pF tolerance value added to the standard arm, the bridge would not reach balance and there would be no phase inversion. But with the 5 pF added to the Test Arm, the bridge would pass through balance for a "High" decision.

3.5.4 When the decision output of the phase sensitive detector shifts from "High" to "Low" on each successive half cycle, special circuitry disables the "High" and "Low" indicators, activating only the "Go" indicator.

3.6 Test Decision Outputs

3.6.1 Test results are indicated by red, yellow, and green panel lamps representing "Hi", "Lo", and "Go" decisions, respectively. Three contact closures (one for each test result) with floating common connection are provided at the rear terminal panel. A sample of the 6.3V, line frequency, filament voltage to each of the three indicating lamps is also provided at this panel.

SECTION IV

Operating Procedures

Important Note

Operating techniques and procedures for this instrument are substantially different from those for conventional capacitance bridges. Gross inaccuracies may result if correct operating procedures are not followed. For this reason we strongly urge that this section be read in its entirety by the user.

4.1 Basic Capabilities

4.1.1 This instrument may be used for three types of capacitance or inductance measurements:

a. Automatic, dual-limit (HI/LO/GO) testing, which determines whether the specimen is within, below, or above the pre-set tolerance limits.

b. Automatic, single-limit (HI/LO) testing, which determines whether the specimen is above or below a pre-set value.

c. Manual measurements in the manner of a conventional laboratory bridge.

4.1.2 In automatic dual-limit or single-limit testing the bridge is insensitive to the loss of the specimen. In manual measurements this insensitivity to loss may be maintained if capacitance measurements alone are desired, or the conductance may be balanced and read in the usual fashion.

4.2 Controls and Their Functions

4.2.1 TOL IN/TOL OUT

The TOL IN/TOL OUT selector switches the tolerance amplifier on (TOL IN) or off (TOL OUT). This selector should be in the TOL IN position only when dual-limit tests of capacitance or inductance are to be made. For single-limit testing, in which the tolerance is effectively zero, and for manual measurements in which no tolerance limits are involved, this switch should be in the TOL OUT position.

See also "Special Note for Instruments, Serial Number 184 and Below", paragraph 4.3.5.

4.2.2 TOL ± pF

In conjunction with the associated tolerance multiplier, this control establishes symmetrical tolerance limits in terms of picofarads. It should be noted that the calibrations on this control are not precise and are intended to serve primarily as a guide in setting up the desired tolerance limits in accordance with the procedure outlined in paragraph 4.6.3.

4.2.3 TOL MULT

This selector provides four miltiplier ranges of tolerance limits. See paragraph 4.3.4 for special precautions concerning settings of the TOL MULT selector.

4.2.4 PHASE ADJ

Phase adjustment is required to assure insensitivity of the phase-sensitive detector to the loss of the specimen, unless the Q of the specimen is known to be greater than 1000, in which case setting the PHASE ADJ control at 12 o'clock suffices. Phase adjustment is not required for manual measurements when the conductance is to be balanced out.

4.2.5 MULTIPLY C

Provides 4 capacitance ranges in decade steps. The selected multiplying factor also equals the value in pF of a major division on the capacitance vernier scale.

4.2.6 TEST LEVEL ADJ

Provides continuous control of test signal level from 1 mV to 250 mV. Test signal should be set to maximum (full CW) unless a specific test signal level is required. For automatic dual-limit testing, the signal level should not be less than 15 mV.

4.2.7 DIVIDE G/MULTIPLY R

Provides 4 decade ranges of conductance (resistance)

4.2.8 CAPACITANCE pF

Main capacitance balance control. The "counter" dial plus vernier reads directly in pF. When the indicating hairline lies over the black portion of the counter dial, the black numerals on the vernier are used; when over the red portion, the red numerals are used.

4.2.9 CONDUCTANCE

Main conductance balance control; calibrated in both micromhos and ohms.

4.2.10 C ZERO

Capacitance zero balance adjustment

4.2.11 R/G ZERO

Conductance zero balance adjustment

4.2.12 C/L

Permits either direct-reading capacitance measurements (C position) or determination of equivalent parallel inductance by computation (L position).

4.2.13 ADJUST (DC Bias)

Adjusts the level of dc bias (internal only); connections for metering internal bias voltage and current (simultaneously if desired) are located immediately to the right of this control.

4.2.14 + INT/OFF/-INT/EXT (DC Bias)

Selects positive or negative internal bias, or external bias. Connections for external bias are located immediately to the right of this selector.

4.2.15 NULL INDICATOR

Meter-type, amplitude sensitive null indicator; continuously minotors the output level of the bridge.

4.2.16 PANEL LAMPS (Test Decision Indicators)

Three indicator lamps are operated by the phase sensitive detector. Yellow lamp lights when capacitance in the standard arm is greater than that in the test arm; the red lamp lights when the reverse condition exists. Balance is indicated by the cross-over point between the two.

The green panel lamp indicates that the balance point of the bridge lies within the programmed tolerance limits and is generally used only for automatic dual-limit testing.

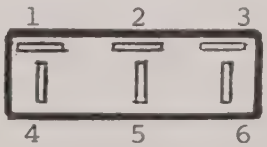
Note: Since the phase sensitive detector is not affected by the loss of the specimen, these panel lamps indicate the capacitance balance only. Thus when zero-balancing the bridge or when manual measurements of capacitance and loss are being made, the indicating meter, not the lamps, should be used for null detection.

As long as the bridge is turned on, one of these three lamps should always be lighted, regardless of any control settings. In this sense, the lamps serve as pilot lamps as well.

4.2.17 REAR PANEL CONNECTOR

Duplications of visual test decisions are available as continuity contacts at a rear panel connector. Pin identification is as follows:

1. Ground
2. Go (green)
3. Common



4. 6.3 v, ac
5. HI (red)
6. LO (yellow)

4.3 Special Operating Characteristics

4.3.1 Zero Balance

The zero balance should be checked and the bridge re-zeroed if necessary, according to the procedure outlined in paragraph 4.5, when:

a. The instrument is turned on and has completed warm-up (see paragraph 4.4)

b. The setting of either the MULTIPLY C or the DIVIDE G/MULTIPLY R selector is changed.

c. The C/L selector is switched from one setting to the other.

d. The position of the TOL IN/TOL OUT switch is changed.

e. The level of the test signal is altered.

f. Any change is made in the length or type of external test leads, or in the type of external test fixture.

4.3.2 Null Detection

The decision output lamps may be used for indication of the capacitance balance of the bridge, with balance being the point at which illumination switches from red to yellow (or vice-versa). It will be noted that even when no tolerance limits are programmed and with the TOL IN/TOL OUT switch in the TOL OUT position, the green lamp flashes momentarily during the cross-over from yellow to red (or vice-versa). This is wholly without significance when operating manually or when making single limit tests.

The cross-over point is a "knife-edge" condition and, with no tolerance limits programmed, it is generally impossible to adjust the main capacitance dial so that the green light alone stays lighted unless a low (approximately 15 millivolts or less) test signal level is used. With low test signal level, system noise tends to broaden the null so that the precise point of balance may be indicated by the green lamp alone or by the flickering of all three simultaneously.

4.3.3 Conductance Balance

While the phase sensitive detector is essentially unaffected by conductance, it will be noted that changes in setting of either the main conductance balance control, R/B ZERO control, or the G/R MULTIPLIER have an effect on the decision output lamps because of changes in the distributed capacitance in the conductance network. For this reason these controls should be left undisturbed during the course of capacitance tests or measurement, except when condutance is being balanced.

If difficulty is experienced in balancing conductance (especially on the lower conductance ranges) using the conductance dial itself in the initial balancing step will prove helpful, as outlined in the zero balance procedure (see paragraph 4.5)

4.3.4 Tolerance Limits

When the TOL IN/TOL OUT switch is in the TOL IN position, any limit value set up by the tolerance controls is naturally applied to the bridge. When zero balancing, it is extremely important to assure that limits have not inadvertantly been left standing, since this could cause gross inaccuracies in zero setting.

Please note that when in the TOL IN Mode, the distributed capacitance of the tolerance network is applied to the bridge as a limit value unless the TOL MULT selector is set to the .01 position, even if the TOL ± pF control is set to Zero.

4.3.5 SPECIAL NOTE FOR INSTRUMENTS WITH SERIAL NOS. OF 184 OR BELOW

In instruments having serial numbers of 184 or below, the TOL IN/TOL OUT selector does not completely disable the tolerance amplifier. Even with this switch in the TOL OUT position, any programmed tolerance value will appear as additional capacitance in the standard arm. In these instruments the TOL ± pF control MUST be set to Zero and the TOL MULT selector to .01 at any time that a specific tolerance value is not desired, regardless of the TOL IN/TOL OUT setting.

4.4 Turn-on and Warm-up Procedure

Connect the bridge to an appropriate power source (see voltage and frequency requirements on the instrument's identification plate). A warm-up period of at least 15 minutes should be allowed for manual operation. For automatic single-limit or dual-limit testing a one-hour warm-up should be allowed to assure thermal stabilization of the phase detector.

4.5 Zero-Balancing the Bridge

The zero balance of the bridge should be checked and the bridge re-zeroed if necessary under each of the circumstances noted in paragraph 4.3.1. (Note: The instrument should be warmed up for at least 15 minutes before zero-balancing is attempted.)

To zero-balance the bridge, proceed as follows:

a. Set the C/L switch to the C position if capacitance tests are to be made, or to the L position for inductance measurements.

b. Set the TOL IN/TOL OUT switch to TOL IN if preparing for dual-limit test; to TOL OUT for single-limit tests or manual measurements.

c. Set the TOL ± pF control to zero; set the TOL MULT selector to .01 (see paragraph 4.3.4 above)

d. Set the MULTIPLY C and the DIVIDE G/MULTIPLY R switches in accordance with the range of the test. (see Table 4-1a or 4-1b)

e. Set the PHASE ADJ, C ZERO, and R/G ZERO controls to 12 o'clock.

f. Connect any external test leads and test fixture to be used to the test connectors (see Section 5 for connection techniques).

g. Set the main capacitance and conductance dials to zero (be sure that BOTH the counter and vernier of the main capacitance dial are at zero).

h. Set the TEST LEVEL ADJ control full clock-wise for maximum test signal level, unless a specific test level is desired. In such a case, the level may be set to the desired value by connecting a suitable VTVM (One of the Boonton Electronics 91 Series RF Voltmeters or equivalent) between the Lo post and ground and adjusting the TEST LEVEL ADJ control as required.
Note: For dual-limit testing, test signal level must be at least 15 mV.

i. By successive adjustments of the C ZERO and R/G ZERO controls, bring the bridge to balance as indicated by a minimum reading on the NULL INDICATOR meter.

See note regarding R/G ZERO adjustment on X1 DIVIDE G/MULTIPLY R range; Item K below.

j. Move the main capacitance control slightly (an amount approximately equal to the resolution of the bridge for the range employed) to the left and right of 0. The amber and red lamps should light alternately with this motion, with the cross-over point exactly at 0. Readjust the C ZERO control to obtain this condition, if necessary. (See paragraph 4.3.2 for additional details on null detection.)

k. Note: When using the X1 DIVIDE G/MULTIPLY R range, it is advisable to deviate from the above procedure to zero balance conductance. On this multiplier range the R/G ZERO control is relatively insensitive in comparison to the main conductance dial. To zero balance conductance on this range, set the R/G ZERO control to 12 o'clock and balance with the

main conductance dial (capacitance balancing is performed in the manner described above.) Conductance balance should be achieved within +1 minor division from zero on the conductance scale.

If conductance readings are to be made in subsequent tests, the amount of offset from zero is added to or subtracted from the dial reading to obtain the correct value.

With these steps completed, the bridge is zero-balanced and ready for operation.

Table 4-1a

Control Settings for Dual or Single Limit Testing

C Test Range, pF	C MULT Setting	G/R Mult Setting	G DIAL Setting for Phase Adjust
100 to 1000	x1	x10	1K (Ω)
10 to 100	x.1	x10	3K (Ω)
1 to 10	x.01	x100	-100 µmho*
0.1 to 1	x.001	x100	-100 µmho*

* Red subcalibration farthest to the left from zero on the conductance scale.

Note: To set tolerance limits, use lowest TOL MULT position possible to give desired value (in conjunction with the TOL ± PF control). The x20 position should be used only when no other setting will give the desired value, since on this position sensitivity is somewhat reduced.

For procedure to increase accuracy of tests of low Q components, see paragraph 4.13.

Table 4-1b

Control Settings for Manual Measurements

C Test Range, pF	MULTIPLY C Setting
100 to 1000	x1
10 to 100	x.1
1 to 10	x.01
0 to 1	x.001

DIVIDE G/MULTIPLY R: If the general range of conductance of the specimen is known, set this multiplier accordingly. Otherwise, start at X1000 and work down until reading is obtained between 100 and 1000 on the scale.

4.6 Automatic, Dual-Limit Capacitance Testing

4.6.1 Before testing, the bridge should be zeroed on the appropriate range (with the TOL IN/TOL OUT switch in the TOL IN position) by following the procedure of paragraph 4.5. Dual-limit tests should not be attempted with a test signal level below 15 mV. Whenever possible, maximum level (TEST LEVEL ADJ control full clockwise) should be used to assure the highest possible resolution.

4.6.2 The PHASE ADJ control must be adjusted unless the Q of the specimen is KNOWN to be greater than approximately 1000. The phase adjustment is made in the following manner:

a. Check to assure that the bridge is properly zeroed. Re-zero if necessary.

b. Move the main conductance control from its zero setting to the phase adjustment position shown in Table 4-1.

c. Adjust the PHASE ADJ control until the red and yellow lamps are at the cross-over point.

d. Return the main conductance control to zero

4.6.3 Tolerance limits are established in the following manner:

a. Set the main capacitance dial to the desired symmetrical tolerance value (expressed in $\pm$ pF).

b. Set the TOL MULT selector to the position indicated for the desired test range as shown in Table 4-1.

c. Adjust the TOL $\pm$ pF control just to the point at which the decision indicator switches from yellow to give a steady green output. (Note: Calibration of the TOL $\pm$ pF control is not precise and is intended only as a guide for "rough" adjustment. By the above procedure, tolerance limits are set with the accuracy of the bridge itself.)

d. Set the main capacitance dial to the nominal value of the test.

4.6.4 Automatic, dual-limit tests are now made simply by placing the specimen in the test terminals or test fixture and observing the test results at the decision indicators or outputs. (see paragraph 4.6.5)

Details on remote connection methods and the use of remote test fixtures are provided in section 5 of this instruction book.

4.6.5 Dual-Limit Test Decision Outputs

Test decisions are indicated at the front panel as follows:

Yellow = Test capacitance lower than tolerance limit
Green = Test capacitance within tolerance limits
Red = Test capacitance above tolerance limits

4.6.6 Continuity closures duplicating the front panel decision outputs are available at a rear 6-connector socket. (see paragraph 4.2.17) A mating 6-pin plug is provided for connection to external equipment.

Typical load capability of the contact closures (mercury relays) is 100 V/A up to 500 V. (For inductive loads adequate protection should be provided.)

A constant source of 6.3 V, ac, is provided at this plug, when used in conjunction with the contact closures, it provides power for remote decision indication.

4.7 Single-Limit Capacitance Tests

4.7.1 With the C/L selector at C and the TOL IN/TOL OUT switch at TOL OUT, assure that the instrument is properly zero-balanced.

Unless the test specimens are known to have a Q of 1000 or greater, perform the phase adjustment, as outlined in paragraph 4.6.2.

Set the main capacitance dial to the desired limit value, and connect the specimen, and observe the test decision. (see paragraph 4.7.2)

When it is desired to determine the exact value of the test specimen, simply rotate the main capacitance dial (CCW if the indication is red; CW, if yellow) until the point of cross-over, and read the value from the capacitance dial. When the dial is returned to the desired single-limit value, testing may proceed as before.

4.7.2 Single-Limit Test Decision and Outputs

High/Low (with respect to the programmed limit value) test results are indicated as follows:

Red = Specimen value higher than limit
Yellow = Specimen value lower than limit

As in the case of dual-limit testing, decision outputs are also available in electrical form at the rear connector.

4.8 Manual Measurements of Capacitance and Conductance

4.8.1 With the TOL IN/TOL OUT selector in the TOL OUT position, the C/L switch set to C, and the bridge zeroed as described in paragraph 3.4, the instrument may be used as a standard laboratory bridge for the measurement of capacitance and conductance.

IMPORTANT: For instruments having serial number 184 or below, see special note, paragraph 4.3.4.

With the test specimen installed, by successive adjustments of the capacitance and conductance dials, achieve a minimum deflection on the null indicating meter. Note: The indicating lamps should not be used for null detection when both capacitance and conductance readings are to be made. If just the capacitance value is to be read, the yellow-red cross-over may be used for null indication (after setting PHASE ADJ as outlined in paragraph 4.6.2).

The null point should occur between the 100 and 1000 on both the CAPACITANCE AND CONDUCTANCE dials. Otherwise the adjacent MULTIPLY C and/or DIVIDE G/MULTIPLY R range should be selected. (Note: When the setting of either multiplier control is changed, the zero balance of the bridge should be checked and readjusted if required.

4.9 Interpreting Manual Readings

4.9.1 After the capacitance and conductance have been properly balanced as described above (paragraph 4.8) the capacitance dial (reading times MULTIPLY C setting), and conductance or equivalent parallel resistance from the main conductance dial (conductance reading divided by, or resistance reading multiplied by the DIVIDE G/MULTIPLY R setting.)

4.10 Inductance Tests and Measurements

All preliminary procedures for inductance tests or measurements are identical to those for capacitance with the following exceptions:

a. The C/L selector is placed in the L rather than the C position (see paragraph 4.5 a)

b. The functions of the STANDARD and TEST terminals are reversed so that the test specimen or remote cables are connected to the STANDARD HI and LO terminals, rather than to the TEST side.

4.11 Dual or Single Inductance Limit Tests

Inductance limit testing proceeds exactly as capacitance

testing. To determine proper settings for nominal and limit values, convert inductance to the equivalent capacitance value from the expression:

$$C = \frac{25.33}{L}$$

Where C = capacitance in picofarads
L = inductance in millihenries

Inductance test decisions are issued as follows:

a. Dual Limit
Red indicator = Test inductance below limit
Green indicator = Test inductance within limits
Yellow indicator = Test inductance above limit

b. Single Limit
Red indicator = Test inductance LO
Yellow indicator = Test inductance HI

Test decisions are duplicated in continuity form at the rear-panel connector. Note: Inductance HI and LO test decisions are reversed with respect to those for capacitance.

4.12 Manual Inductance Measurements

Manual inductance measurements are made by the same procedure as manual capacitance measurements. The inductance value is determined from the expression:

$$L = \frac{25.33}{C}$$

Where L = inductance in millihenries
C = value in picofarads read from main capacitance dial x MULTIPLY C position.

TABLE OF REPLACEABLE PARTS
FOR 77B

NOTE: Components in the "Bridge" unit have not been included since, in general, their replacement must be followed by adjustments that require specialized equipment and techniques.

- CAPACITORS -

Reference		Description				BEC Part No.
C101	Durmica	150 pF	±5%	500 V	ARCO DM-15-151J	200,032
C102	Mylar	0.002 µF	±5%	200 V	Sprague	234,024
C103	Mylar	0.1 µF	±20%	200 V	Sprague	230,116
C104	Durmica	120 pF	±5%	500 V	ARCO DM-15F-121J	200,002
C105	Mylar	0.1 pF	±20%	200 V	Sprague	230,116
C106	Durmica	300 pF	±5%	500 V	ARCO DM-15-301J	200,034
C107	Tubular	36 pF	±5%	N750 ppM/°c	Erie 301-651-U2	200,117
C108	Var.Air	1 to 15 pF			Jackson Bros. Type C808	275,123
C109	Durmica	120 pF	±5%	500 V	ARCO DM-15F-121J	200,002
C110	Mylar	0.1 µF	±20%	200 V	Sprague	230,116
C111	Durmica	120 pF	±5%	500 V	ARCO DM-15F-121J	200,002
C112	Paper	0.5 µF		200 V	Aerovox P8292ZN12	230,135
C113	Durmica	300 pF	±5%	500 V	ARCO DM-15-301J	200,034
C114	Mylar	0.1 µF	±20%	200 V	Sprague	230,116
C115	Mylar	0.1 µF	±20%	200 V	Sprague	230,116
C116	Durmica	300 pF	±5%	500 V	ARCO DM-15-301J	200,034
C117	Durmica	10 pF	±5%	500 V	ARCO DM-10C-100J	200,022
C118	Durmica	330 pF	±1%	500 V	ARCO DM-15-331F	200,033
C119	Durmica	330 pF	±1%	500 V	ARCO DM-15-331F	200,033
C120	Durmica	300 pF	±5%	500 V	ARCO DM-15-301J	200,034
C121	Durmica	300 pF	±5%	500 V	ARCO DM-15-301J	200,034
C123	Mylar	0.1 µF	±20%	200 V	Sprague	230,116
C124	Mylar	0.047 µF	±10%	400 V	Sprague 192P47394	234,047
C125	Mylar	0.1 µF	±20%	200 V	Sprague	230,116
C126	Mylar	0.01 µF	±20%	200 V	Sprague	234,027
C127	Durmica	300 pF	±5%	500 V	ARCO DM-15-301J	200,034
C128	Durmica	300 pF	±5%	500 V	ARCO DM-15-301J	200,034
C129	Durmica	300 pF	±5%	500 V	ARCO DM-15-301J	200,034
C130	Durmica	300 pF	±5%	500 V	ARCO DM-15-301J	200,034
C131	Mylar	0.002 µF	±5%	200 V	Sprague	234,024
C132	Mylar	0.002 µF	±5%	200 V	Sprague	234,024
C133	Electrolytic	50 µF		25 V	Sprague TE-1209	283,159
C134	Electrolytic	50 µF		25 V	Sprague TE-1209	283,159
C136	Durmica	470 pF	±5%	500 V	ARCO DM-15-471J	200,028
C201	Mylar	0.01 µF	±20%	400 V	Sprague	234,021
C202	Durmica	150 pF	±5%	500 V	ARCO DM-15-151J	200,032
C203	Durmica	68 pF	±5%	500 V	ARCO DM-15-680J	200,031

Reference		Description				BEC Part No.
C204	Mylar	0.1 µF	±20%	200 V	Sprague	230,116
C205	Var. Air	50 pF			Hammerlund MAPC-50	275,103
C206	Durmica	330 pF	±1%	500 V	ARCO DM-15-331F	200,033
C207	Mylar	0.01 µF	±20%	200 V	Sprague	234,027
C208	Durmica	68 pF	±5%	500 V	ARCO DM-15-680J	200,031
C209	Mylar	0.1 µF	±20%	200 V	Sprague	230,116
C210	Mylar	0.1 µF	±20%	200 V	Sprague	230,116
C211	Mylar	0.01 µF	±20%	200 V	Sprague	234,027
C212	Mylar	0.01 µF	±20%	200 V	Sprague	234,027
C213	Paper	1.0 µF	±20%	100 V	Electron WI-105	236,007
C214	Mylar	0.1 µF	±20%	200 V	Sprague	230,116
C301	Electrolytic	20-20 µF		450 V	Mallory FP-234	283,100

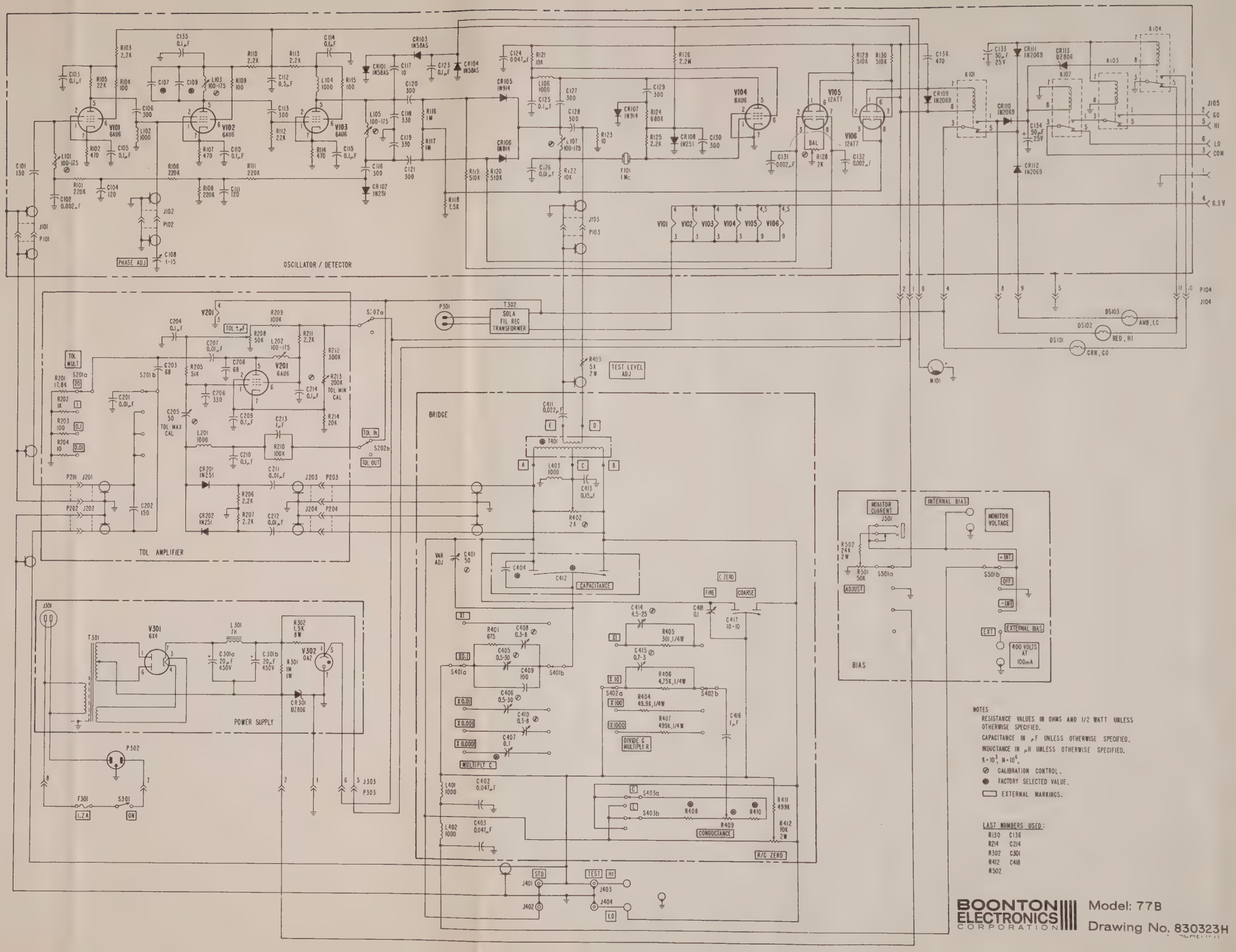
NOTE: Above voltage rating are working volts.

- RESISTORS -

Reference		Description				BEC Part No.
R101	Comp.	220 K	±5%	1/2 Watt	AB Type EB	301,143
R102	Comp.	470 Ω	±5%	1/2 Watt	AB Type EB	301,079
R103	Comp.	2.2 K	±5%	1/2 Watt	AB Type EB	301,095
R104	Comp.	100 Ω	±5%	1/2 Watt	AB Type EB	301,063
R106	Comp.	220 K	±5%	1/2 Watt	AB Type EB	301,143
R107	Comp.	470 Ω	±5%	1/2 Watt	AB Type EB	301,079
R108	Comp.	220 K	±5%	1/2 Watt	AB Type EB	301,143
R109	Comp.	100 Ω	±5%	1/2 Watt	AB Type EB	301,063
R110	Comp.	2.2 K	±5%	1/2 Watt	AB Type EB	301,095
R111	Comp.	220 K	±5%	1/2 Watt	AB Type EB	301,043
R112	Comp.	22 K	±5%	1/2 Watt	AB Type EB	301,119
R113	Comp.	2.2 K	±5%	1/2 Watt	AB Type EB	301,095
R114	Comp.	470 Ω	±5%	1/2 Watt	AB Type EB	301,079
R115	Comp.	100 Ω	±5%	1/2 Watt	AB Type EB	301,063
R116	Comp.	1 M	±5%	1/2 Watt	AB Type EB	301,159
R117	Comp.	1 M	±5%	1/2 Watt	AB Type EB	301,159
R118	Comp.	7.5 K	±5%	1/2 Watt	AB Type EB	301,108
R119	Comp.	510 K	±5%	1/2 Watt	AB Type EB	301,152
R120	Comp.	510 K	±5%	1/2 Watt	AB Type EB	301,152
R121	Comp.	10 K	±5%	1/2 Watt	AB Type EB	301,111
R122	Comp.	10 K	±5%	1/2 Watt	AB Type EB	301,111
R123	Comp.	10 Ω	±5%	1/2 Watt	AB Type EB	301,039
R124	Comp.	680 K	±5%	1/2 Watt	AB Type EB	301,155
R125	Comp.	2.2 K	±5%	1/2 Watt	AB Type EB	301,095
R126	Comp.	2.2 M	±5%	1/2 Watt	AB Type EB	301,167
R128	Var.	2 K Trimpot	±10%	1/4 Watt	Bourns 200L-1-202	311,203
R129	Comp.	510 K	±5%	1/2 Watt	AB Type EB	301,152
R130	Comp.	510 K	±5%	1/2 Watt	AB Type EB	301,152

Reference		Description				BEC Part No.
R201	Dep. Car.	17.8 K	±1%	1/2 Watt	Dale Type DCS 1/2	306,388
R202	Dep. Car.	1 K	±1%	1/2 Watt	Dale Type DCS 1/2	306,239
R203	Dep. Car.	100 Ω	±1%	1/2 Watt	Dale Type DCS 1/2	306,120
R204	Dep. Car.	10 Ω	±1%	1/2 Watt	Dale Type DCS 1/2	306,000
R205	Comp.	51 K	±5%	1/2 Watt	AB Type EB	301,128
R206	Comp.	2.2 K	±5%	1/2 Watt	AB Type EB	301,095
R207	Comp.	2.2 K	±5%	1/2 Watt	AB Type EB	301,095
R208	Var.	50 K	±5%	10 Turn WW	Clarostat 62-JA-50K	311,196
R209	Dep. Car.	100 K	±1%	1/2 Watt	Dale Type DCS 1/2	306,478
R210	Comp.	100 K	±5%	1/2 Watt	AB Type EB	301,135
R211	Comp.	2.2 K	±5%	1/2 Watt	AB Type EB	301,095
R212	Comp.	300 K	±5%	1/2 Watt	AB Type EB	301,146
R213	Var.	200 K	Trimpot	0.2 Watt	Bourns 276-1-204	311,204
R214	Dep. Car.	20 K	±1%	1/2 Watt	Dale Type DCS 1/2	306,395
R301	Comp.	1 M	±20%	1 Watt	AB Type GB	301,128
R302	Wirewound	1.5 K	±5%	8 Watt	Ohmite #1536	301,315
R501	Var.	50 K	±5%	10 Turn WW	Clarostat 62-JA-50K	311,198
R502	Comp.	24 K	±5%	2 Watt	AB Type HB	304,120
CR101	Diode	1N-58AS	Germanium		Sylvania	530,021
CR102	Diode	1N-251	Silicon		Texas Instrument	530,043
CR103	Diode	1N-58AS	Germanium		Sylvania	530,021
CR104	Diode	1N-58AS	Germanium		Sylvania	530,021
CR105	Diode	1N-914	Silicon		Texas Instrument	530,058
CR106	Diode	1N-914	Silicon		Texas Instrument	530,058
CR107	Diode	1N-914	Silicon		Texas Instrument	530,058
CR108	Diode	1N-251	Silicon		Texas Instrument	530,043
CR109	Diode	1N-2069	Silicon		Texas Instrument	530,053
CR110	Diode	1N-2069	Silicon		Texas Instrument	530,053
CR111	Diode	1N-2069	Silicon		Texas Instrument	530,053
CR112	Diode	1N-2069	Silicon		Texas Instrument	530,053
CR113	Diode	UZ-806	Zener		Unitrode	530,041
CR201	Diode	1N-251	Silicon		Texas Instrument	530,043
CR202	Diode	1N-251	Silicon		Texas Instrument	530,043
CR301	Diode	UZ-806	Zener		Unitrode	530,041
DS101	Light	Limit	Green		Dialco #101-5030-972	474,110
DS102	Light	Limit	Red		Dialco #101-5030-971	474,109
DS103	Light	Limit	Yellow		Dialco #101-5030-976	474,112
F301	Fuse	1.2 A @ 125 V (Slo-blo)			Buss MDL 1 2/10	545,509
K101	Relay	Mercury Wetted Contacts			Adlake MWSL-16012-1B	471,005
K102	Relay	Mercury Wetted Contacts			Adlake MWSL-16012-1B	471,005

Reference		Description				BEC Part No.
K103	Relay	Mercury Wetted Contacts			Adlake MWSL-16012-1B	471,005
K104	Relay	Mercury Wetted Contacts			Adlake MWSL-16012-1B	471,005
L101	Coil, Var.,RF	100-175 µH		North Hills	1500 A	400,115
L102	Choke, RF	1000 µH	±5%	Essex	RFC-1	400,095
L103	Coil, Var.,RF	100-175 µH		North Hills	1500 A	400,115
L104	Choke, RF	1000 µH	±5%	Essex	RFC-1	400,095
L105	Coil, Var.,RF	100-175 µH		North Hills	1500 A	400,115
L106	Choke, RF	1000 µH	±5%	Essex	RFC-1	400,095
L107	Coil, Var.,RF	100-175 µH		North Hills	1500 A	400,115
L201	Choke, RF	1000 µH	±5%	Essex	RFC-1	400,095
L202	Coil, Var.,RF	100-175 µH		North Hills	1500 A	400,115
L301	Choke, Power	7 H	500 Ω	50 mA	Stancor C 1707	440,001
M101	Meter	Taut Band	50 mA scale		Weston #1921T	554,140
S201	Switch	Rotary	2P-4T		Oak Type A	466,156
S202	Switch	Slide	DPDT		Oak Type 78	465,112
S301	Switch	Toggle	SPST		Carling #110-63	465,105
S501	Switch	Rotary	2P-4P		Oak Type J	466,171
T301	Transformer	Power	Stancor #1377			446,007
T302	Transformer	6.3 V @ 2.38 A			Sola Type CV-5	466,024
V101	Tube	6AU6				526,6AU6
V102	Tube	6AU6				526,6AU6
V103	Tube	6AU6				526,6AU6
V104	Tube	6AU6				526,6AU6
V105	Tube	12AT7				526,12AT7
V106	Tube	12AT7				526,12AT7
V201	Tube	6AU6				526,6AU6
V301	Tube	6X4				526,6X4
V302	Tube	OA2				526,OA2
Y101	Osc. Crystal	1 Mc		James Knight	CR 18/U	547,015



BOONTON ELECTRONICS CORPORATION

Model: 77B

Drawing No. 830323H

Warranty

Boonton Electronics Corporation warrants its products to the original Purchaser to be free from defects in material and workmanship and to operate within applicable specifications for a period of one year from date of shipment, provided they are used under normal operating conditions. This warranty does not apply to vacuum tubes that have given normal service, to sealed assemblies which have been opened, or to any item which has been repaired or altered without our authorization.

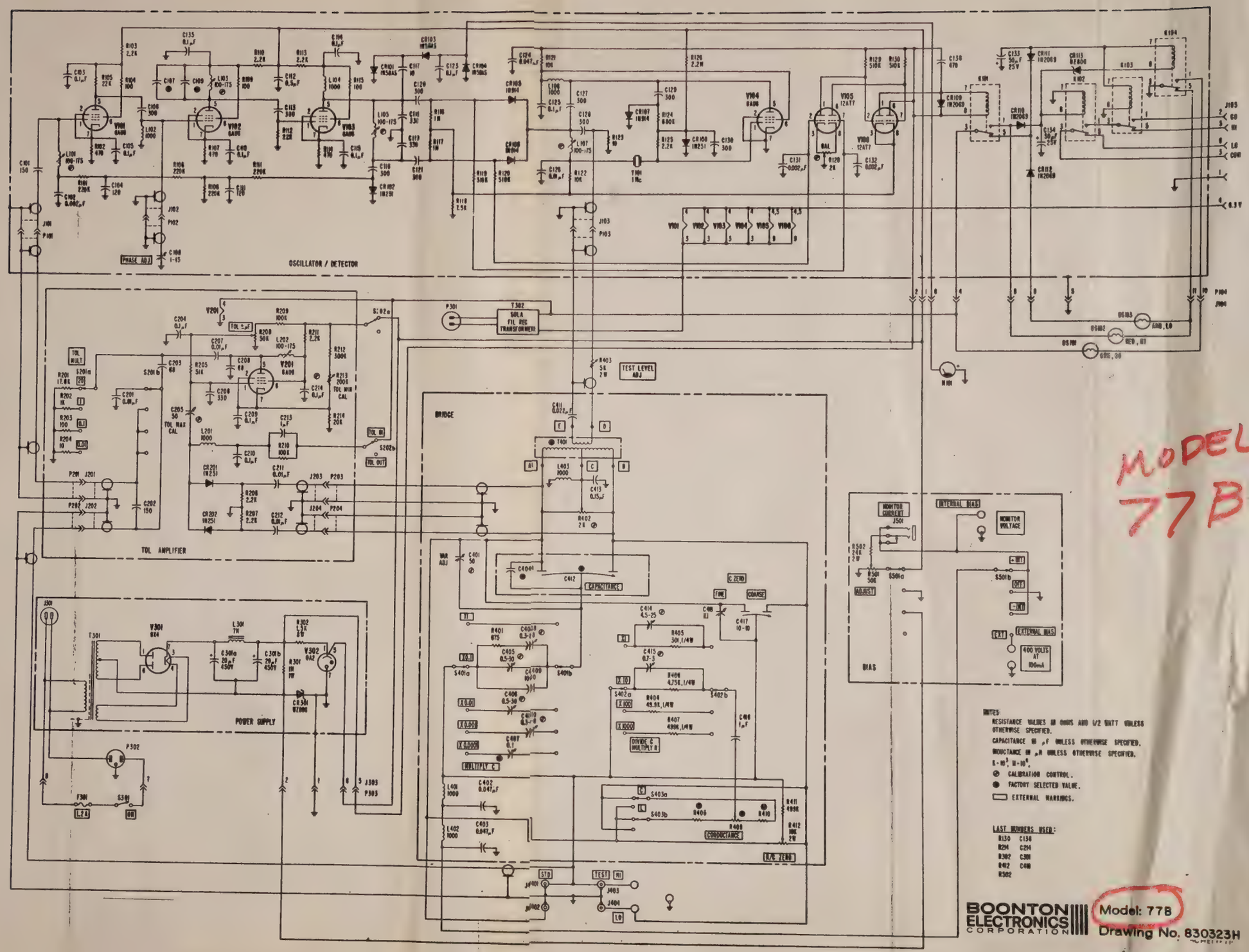
We will repair or, at our option, replace at no charge any of our products which are found to be defective under the terms of this warranty.

SHIPPING INSTRUCTIONS

If it becomes necessary to ship the instrument, the following steps should be followed:

a. Wrap the instrument with heavy wrapping paper and seal the seams with gummed tape. Place in fibreboard carton large enough to permit three inches of soft packing material between instrument and sides of box.

b. Alternatively Boonton Electronics will provide an appropriate shipping container and packing materials at nominal cost. These may be obtained by writing to the Sales Department, Boonton Electronics Corporation, Route 287 at Smith Rd., Parsippany, N. J. 07054.



MODEL 778

BOONTON ELECTRONICS CORPORATION

Model: 778

Drawing No. 830323H

OSCILLATOR / DETECTOR

TOL AMPLIFIER

POWER SUPPLY

CAPACITANCE

NOTES:

RESISTANCE VALUES IN OHMS AND 1/2 WATT UNLESS OTHERWISE SPECIFIED.

CAPACITANCE IN μF UNLESS OTHERWISE SPECIFIED.

INDUCTANCE IN μH UNLESS OTHERWISE SPECIFIED.

$K = \Omega, M = 10^6$.

⊘ CALIBRATION CONTROL.

⊛ FACTORY SELECTED VALUE.

▭ EXTERNAL MARKINGS.

▭ INTERNAL MARKINGS.

LAST NUMBERS USED:

R[illegible]	C[illegible]		
R34	C214		
R[illegible]4	C401		
R412	C417		
RS02			

DRAWN	C.A.M.	3-25-83	
CHKD			
APP'D			
MFG			

778

BOONTON ELECTRONICS

SCHEMATIC

LE & JONES INC.
NEW YORK
67 59

MP MASTER
MA25116